A History of Paired-Watershed Research in the Interior Highlands

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Summary

The USDA Forest Service and its research collaborators have used the paired-watershed approach to study hydrologic processes and their response to forest management within the Interior Highlands for over 70 years. Seven different research areas have been established during this time. These paired-watershed studies have produced important insights concerning soil and water characteristics, processes rates, and the effects of forestry practices on watershed systems within the Interior Highlands. Moreover, these paired-watershed sites have produced several long-term hydrologic data sets that could be used to investigate many additional questions.

Regional Environment

The Interior Highlands physiographic division covers most of northern and western Arkansas, eastern Oklahoma, and southern Missouri (see map).

The climate is humid subtropical. Mean daily summer temperatures range are 70-85 C and 40-50 F in the winter. Mean annual precipitation is 50-55 inch, occurring primarily as rain which is evenly distributed throughout the year.

The Interior Highlands is comprised of three upland sections – the Springfield-Salem Plateaus, the Boston Mountains, and the Ouachita Mountains – and one intervening lowland section – the Arkansas River Valley. The Springfield-Salem Plateaus are composed on flat-lying, limestone and dolomite rocks of Cambrian to Mississippian age. The Boston and Ouachita Mountains are composed of highly folded and faulted sandstones and shales of Pennsylvanian age.

Soils are typically shallow and rocky, especially on slopes. Forest vegetation covers much of the uplands, consisting of varying proportions of pine and hardwood species with hardwoods becoming more dominant northward. Headwater streams in these upland areas are mostly ephemeral.

Methods

Each "paired-watershed" experimental design used three or more sample catchments that were selected based on their environmental similarity.

Each basin was instrumented with sensors to measure hydrologic processes. While sensor technology changed over the years, the same general approach has been used in all areas to monitor hydrologic processes.

Streamflow was quantified by measuring stage within either control structures (e.g., flumes or weirs) or uncontrolled cross-sections.

Precipitation was measured using both storage and recording gauges.

Water samples were taken using either composite or pump samplers.

Total fluvial sediment for individual storms was measured by adding TSS yields to that trapped in approach sections.

A separate meteorological station was usually installed near the basins and instrumented to monitor precipitation, air temperature, wind speed and direction, and barometric pressure

Different "treatments" (e.g., clearcutting, thinning) were then applied to one (or more) of the sample basins with one (or more) basin being left undisturbed (as a control).

The hydrologic responses were then monitored afterwards and compared to the pre-treatment period or to the undisturbed basin response.

Status and Future Opportunities

The Forest Service continues to operate 10 streamflow gauging stations and 2 meteorological stations within the upper Lake Winona basin, while the Weyerhaeuser Co. operates 9 streamflow gauging stations within the Little Glazypeau Creek basin.

There remains much that could be learned using the data sets described here. Some examples of new research might include how forestry practices affect rainfall-runoff relationships; streamflow, sediment, and nutrient routing through larger basins; and flood-frequency and flow duration (especially low-flow) characteristics

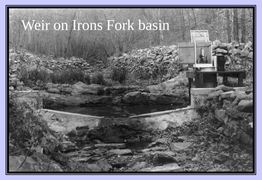
The Irons Fork (1936-1942) Watersheds were part of the Irons Fork Experimental Forest, which began operations in the 1930's and was one of the first such research areas created by the Forest Service.

Objective – To determine the effect of forest management practices on hydrologic processes and to identify silvicultural methods that would aid in regulating streamflow.

Watersheds and Treatments – Four contiguous basins (107-195 ac) were designated for watershed research and measurements began in 1936.

Key Findings – Hydrometeorological research was suspended in 1942 when the onset of World War II forced funding cuts. However, interception data measured at Irons Fork were used by to determine throughfall and stemflow rates for Southern hardwoods and conifers (Helvey and Patric 1965, Helvey 1971).

Proposals to restart the watershed research at Irons Fork continued periodically through the late 1950s, but were never implemented.


Weir on Irons Fork basin


Harvesting on Battiest basin


Phase III station with sampling bridge


Site-preparation burn

Alum Creek Watershed Studies (1960-1996) marked the beginning of research in the Alum Creek Experimental Forest, a 3000-ac area of the Ouachita National Forest.

Objectives – (Smaller basins) To document undisturbed hydrologic characteristics in small headwater basins and assess how these characteristics respond to various silvicultural practices. (Larger basins) To assess channel geometry response to timber harvesting.

Watersheds and Treatments – Three smaller basins (1.28-1.63 ac) and three larger basins (~ 30 ac each). Smaller basin treatments = (1) clearcut or (2) thinned with herbicides; follow-up = (1) burning/replanting or (2) overstory removal. Larger basins treatment = seedtree harvest with 100-ft streamside buffer.

Additional Methods – A series of 15-21 cross-sections were installed along the mainstems of all three larger basins and surveyed roughly quarterly from 1991-1996.

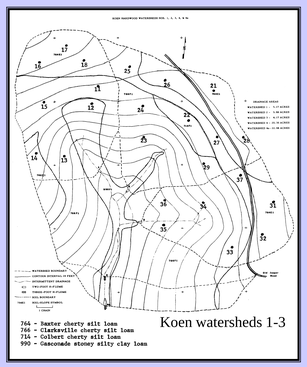
Key Findings -- Small-basin harvest treatments resulted in short-term (1-3 year) increases in annual water yield, annual sediment yields, and mean Na concentrations; and short-term decreases in dormant-season soil-water deficit.

Longer-term (7+ years) decrease in growing season soil water deficits, and increases in mean K and NH_3-N concentrations.

Follow-up treatments resulted in no changes is mean turbidity, herbicide concentrations, and mean Fe, Mn, Ph, and Ca concentrations.

Large basin treatment resulted in no difference in channel geometry metrics between pre- and post-harvest in treated basin, and between it and the two control basins.


3-ft H-flume used in many studies



Koen watersheds 1-3

The Koen Watersheds (1965-1987) are a set of seven small basins located within the 11,000-ac Henry Koen Experimental Forest, and in the headwaters of the Buffalo River, a major drainage within the Springfield-Salem Plateaus section.

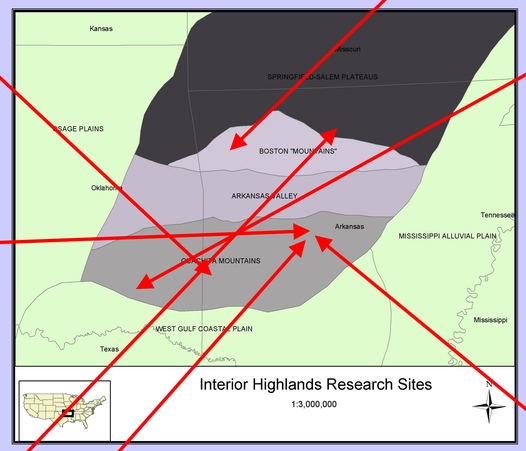
Objectives – Assess how hydrologic characteristics respond to hardwood silvicultural practices.

Watersheds and Treatments – Of the seven, the three smaller basins (4.29-5.76 ac) were selected for a paired-watershed study. One basin was thinned to 60% relative stocking density and undesirable species deadened with herbicide, while second basin was thinned to 40%. Harvesting occurred in 1979.

Key Findings – Pre- vs. post-thinning K and NH_3-N concentrations differed, but differences were not related to treatments.

Fe, Mn, P, K, Ca, Mg, and Na concentrations were unaffected by thinning.

Nutrient concentration variation was generally greater between basins than between pre- vs. post-thinning periods.



The Phase III Watersheds (1996-present) serve as the "core" research area for numerous on-going studies of geomorphic, aquatic, floral, and faunal studies associated with Phase III of the Ecosystem Management Research Program in Arkansas.

Objective – Evaluate how fluvial systems respond at larger spatial scales and to multiple disturbances over time.

Watersheds and Treatments – Four basins (1470-5510 ac) within the Ouachita Mountains with mixed shortleaf pine/hardwood stands were selected on National Forest or Weyerhaeuser land. Within each basin, 2-3 sampling stations were established in a nested design. Treatments = (1) Dispersed stand treatments using a combination of harvest treatments, dormant season burning, and natural regeneration. (2) Clearcutting outside streamside zones with loblolly replanting, selection harvest within streamside zones. (3) Heavy thinning of overstory pine and midstory removal; dormant season burning every 2-5 years, and natural regeneration. (4) Uneven-aged reduction harvest; dormant season burning every 3-5 years, and natural regeneration.

Key Findings – Pending.

The Fleming Creek Watersheds (1972 - 1991) are located within in the Ozark National Forest in the Boston Mountains section.

Objectives – To determine the effects of clearcutting, thinning, and conversion to pine on the basin hydrology.

Watersheds and Treatments – Four basins (14.6-28.3 ac) with mixed shortleaf pine/hardwood stands were used. Treatments = (1) Hardwood deaden with herbicides and replanted with pine; (2) thinning to 56% of original basal area/ (3) clearcut. Treatments were applied in 1982.

Key Findings – Post-treatment data were never analyzed.

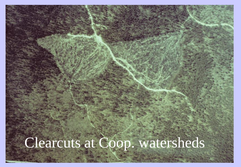
The Battiest Watersheds (1977-1983) were used by the Weyerhaeuser Company to study watershed response to industrial forestry practices in the Ouachita Mountains of Oklahoma.

Objective – To assess the impacts of clearcutting and intensive site-preparation practices on small-basin hydrology.

Watersheds and Treatments – Six basins (4.0-10.4 ac) were paired to create 3 blocks consisting of two basins each. Within each block, one randomly assigned basin was clearcut with residual vegetation crushed, burned, and contour ripped. No roads within basins and no streamside buffers. Replanted with loblolly pine one year after treatment. Treatment occurred in 1978.

Key Findings – Treatment resulted in short-term (1-3 yr) increases in water yield, annual sediment yield, and frequency of higher TSS concentrations.

Treatments did not affect peak streamflow rate.


Clearcuts at Coop. watersheds


Two-years after clearcutting

The Coop. Watersheds (1978-1996) were used for a study in the Ouachita Mountains involving the Forest Service, the Weyerhaeuser Co., the Univ. of Arkansas, and Oklahoma State Univ.

Objective – Evaluate the effects of even-aged and uneven-aged management on water quality and hydrologic responses.

Watersheds and Treatments – Six watersheds were used within the Alum Creek Experimental Forest, and three near Cedar Mountain on Weyerhaeuser lands. The nine basins (10.0-14.6 ac) were divided into three, 3-basin blocks. Treatments = (1) selection cut preceded by herbicide injection of hardwoods, no roads or streamside buffers, and natural regeneration; and (2) clearcut with residual vegetation crushed and burned, no roads or streamside buffers, replanted with loblolly and shortleaf pine.

Key Findings – Short-term increase (1 yr) in annual sediment yield.

No differences in annual water yield, peak streamflow rate, or TSS concentrations.

Acknowledgments

We thank the numerous scientists, resource managers, technicians, students, and volunteers from the Forest Service, Weyerhaeuser Co., and university cooperators who in the past created, maintained, and managed the numerous research sites and stations noted here. We have no doubt that the hard-won data sets resulting from their work will continue to be a tremendous asset in the future as we strive to develop new knowledge and improve forest management in the Interior Highlands.

Additional information and a bibliography of related publications are available from Dan Marion (dmarion@fs.fed.us)